TJNAF E93-050 Nucleon Structure Study by Virtual Compton Scattering

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Virtual Compton Scattering (VCS), which can be studied in the reaction $e+p \to e'+p+\gamma$, is a powerful new tool to access nucleon structure. It is the natural complement to form factor measurements, real Compton scattering ($\gamma + p \to \gamma' + p$), and real- and virtual-photoproduction. The $p(e, e'p)\gamma$ reaction includes the coherent sum of the VCS amplitude and the Bethe-Heitler (BH) or radiative tail amplitude. In the VCS amplitude, a virtual photon of momentum q is exchanged between the electron and the target and the target emits the real photon q'. In the BH amplitude a virtual photon of momentum $q - q'$ is exchanged and the electron emits the photon q' (either before or after emission of the virtual photon).

This experiment will investigate the new field of VCS by detecting the scattered electron and the recoil proton in coincidence in the HRS spectrometers of Hall A. From the known incident beam energy and the measured momenta of the scattered electron and recoil proton, we can reconstruct the missing 4-momentum p_X of the remaining particle in the final state. The VCS events are characterized by the photon mass: $p_X^2 = 0$.

At finite Q^2 but small s (*i.e.* below pion threshold), the $ep \to ep\gamma$ amplitude is completely described by the on-shell proton form factors plus 10 (Q^2-dependent) generalized polarizabilities. These generalized polarizabilities are the allowed amplitudes for an incident C0, C1, C2, E1, E2, or M1 virtual photon and an E1 or M1 outgoing photon (both photons of the same parity). In the real photon limit, only the E1$\otimes$E1 and M1$\otimes$M1 terms remain. These are the electric and magnetic polarizabilities measured in real Compton scattering

Experimentally, as $q' \to 0$ the recoil proton is only slightly perturbed by the outgoing photon. This means that in our experiment almost the entire phase space $M_N^2 < s < (M_N + m_\pi)^2$ for arbitrary $\theta^{\gamma*\gamma}$ (including q' out of plane) is contained in the acceptance of a single $p(e, e'p)X$ coincidence setting of the two CEBAF Hall A spectrometers.

VCS in the nucleon resonance region depends only on the electromagnetic couplings and the total decay widths of the resonances, and does not depend explicitly on the hadronic couplings $N^* \to N\pi$, *etc.* Thus any model of resonance structure will be able to make predictions of VCS, independent of its ability to describe the specific decay channels. The nearby (or on-shell) resonances contribute primarily to the imaginary part of the VCS amplitude, whereas the distant (or off-shell) resonances contribute primarily to the real part of the amplitude. The experiment is sensitive to the phase of the amplitude through the interference between the VCS and BH terms.

For our choice of kinematics in the resonance region, we will first fix $\theta^{\gamma*\gamma} \approx \pi$ (to ensure that the VCS cross section dominates over the BH) and study $p(e, e'p)\gamma$ over the resonance region at $Q^2 = 1.0$ GeV^2. We will also study the Q^2 dependence for $\sqrt{s} \approx 1.5$ GeV, the region of the S_{11} and D_{13} resonances. These resonances have been studied in inclusive (e, e') and have very different Q^2 dependences. Third, we will fix $\sqrt{s} \approx 1.5$ GeV and $Q^2 \approx 1.0$ GeV^2 and measure the distribution in $\theta^{\gamma*\gamma}$. This will permit us to measure the interference between the BH and VCS amplitudes.